Physical Characterization of Laser Interaction and Shock Generation in Laser Shock Processing: Coupled Theoretical-Experimental Analysis

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Physical Characterization of Laser Interaction and Shock Generation in Laser Shock Processing: Coupled Theoretical-Experimental Analysis

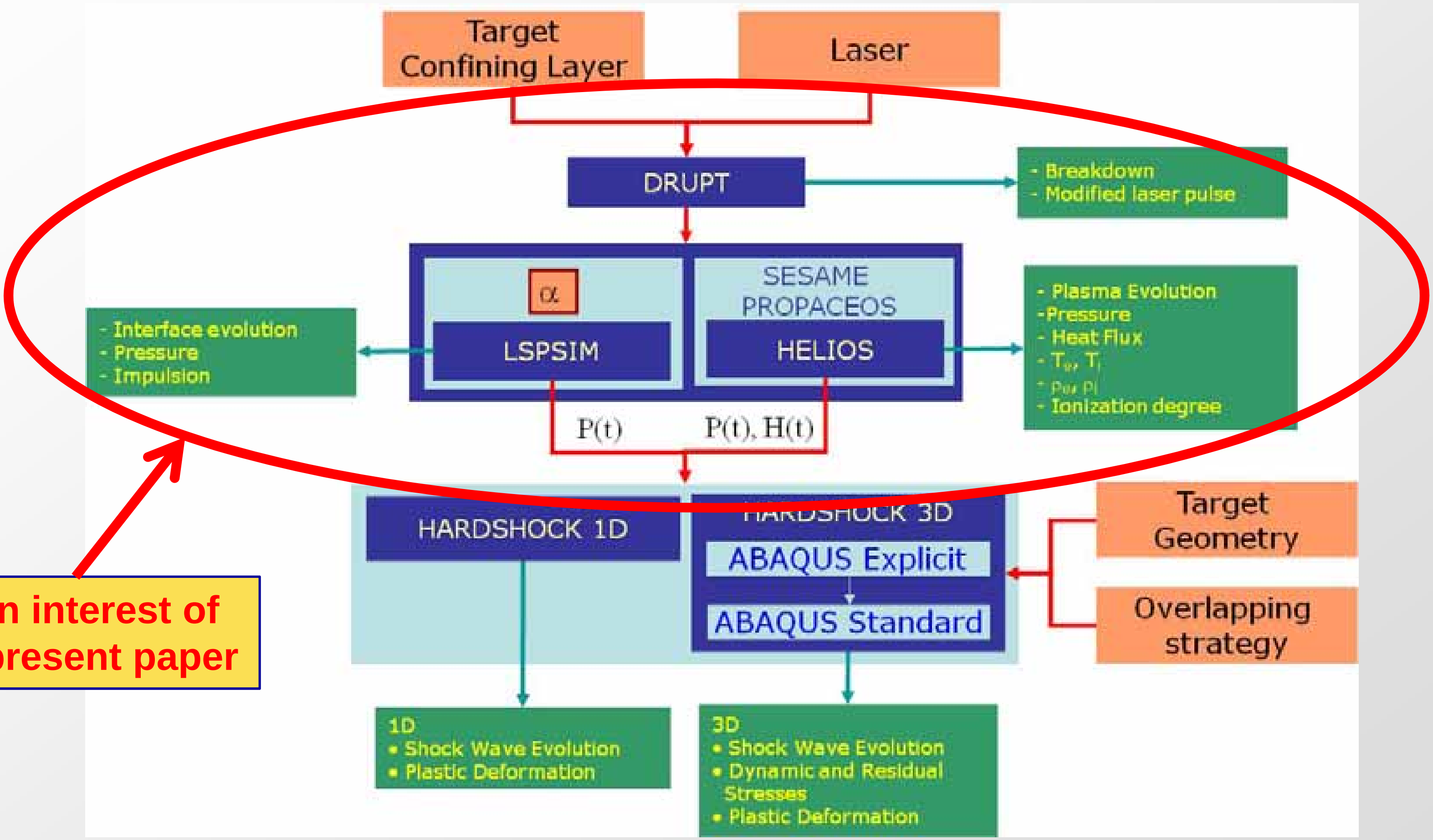
OUTLINE:

- Introduction
- Fundamental Physics of the Laser-Plasma Interaction in Laser Shock Processing
- Theoretical/Computational Model Description
- Some Results. Analysis of Interaction Parameters
- Experimental Validation. Diagnosis Setup
- Discussion and Outlook

1. INTRODUCTION

- Laser Shock Processing (LSP) has been practically demonstrated as a technique allowing the effective induction of residual stresses fields in metallic materials allowing a high degree of surface material protection. Experimental results obtained with commercial Q-switched lasers prove complete feasibility at laboratory scale.
- However, according to the inherent difficulty for prediction of the shock waves generation in the laser generated plasma and its subsequent evolution in treated materials, the practical implementation of LSP processes needs an effective predictive assessment capability.
- A physically comprehensive calculational tool (SHOCKLAS) has been developed able to systematically study LSP processes. It includes the capability of studying from a detailed point of view the laser-plasma interaction, a critical step conditioning the overall process, and the reliable prediction of the thermo-mechanical input source applied to the shocked target for the subsequent solid behaviour calculations.
- Consistently, the appropriate interrelated experimental diagnosis system has been developed for a practical guidance of experimental parameters selection.

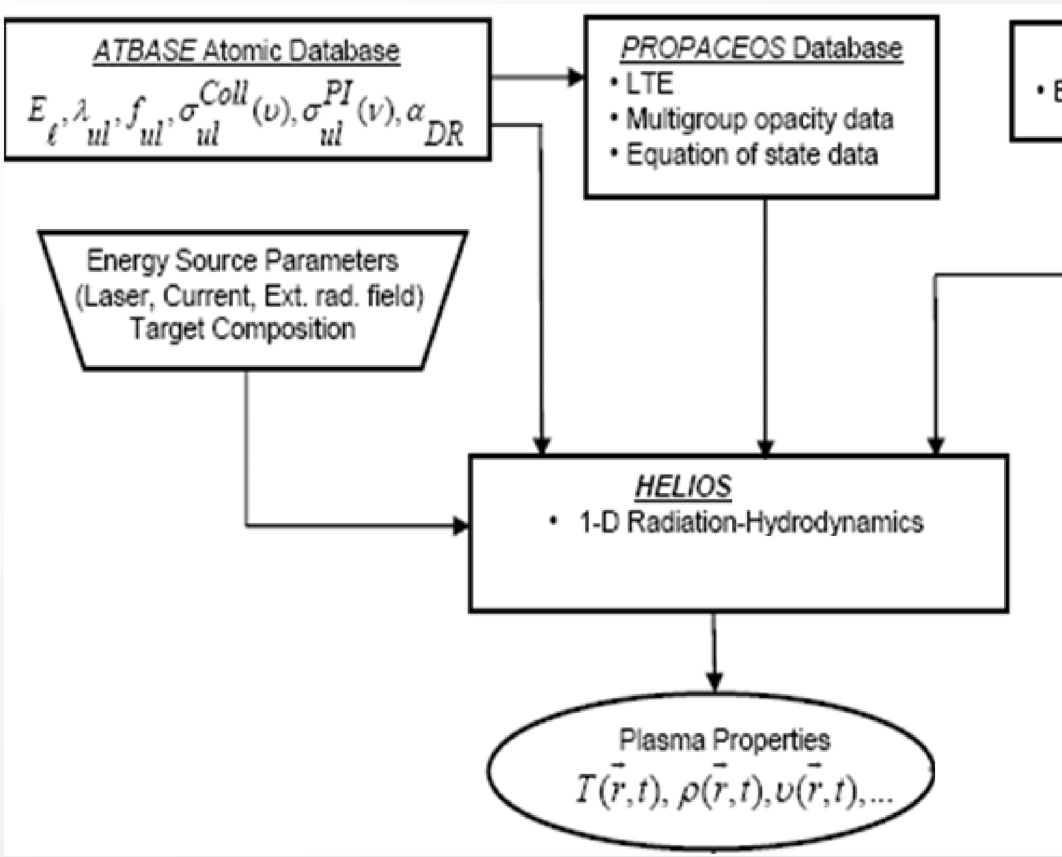
The SHOCKLAS Calculational System

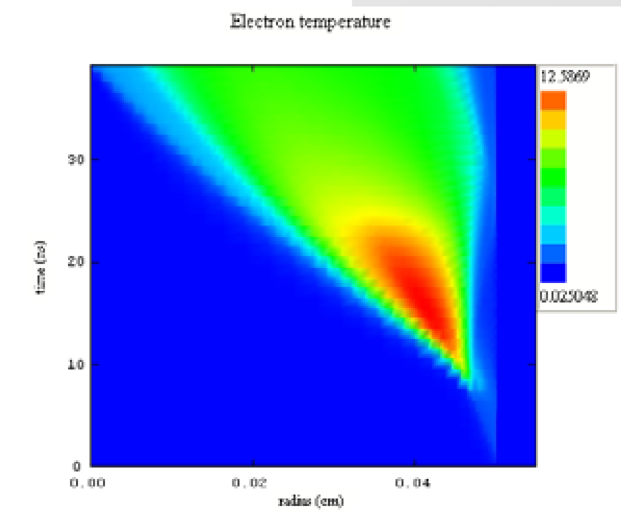


Main interest of the present paper

2. NUMERICAL SIMULATION. MODEL DESCRIPTION

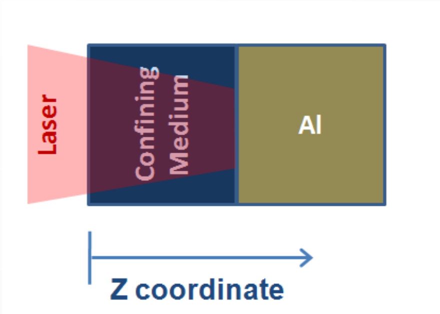
HELIOS

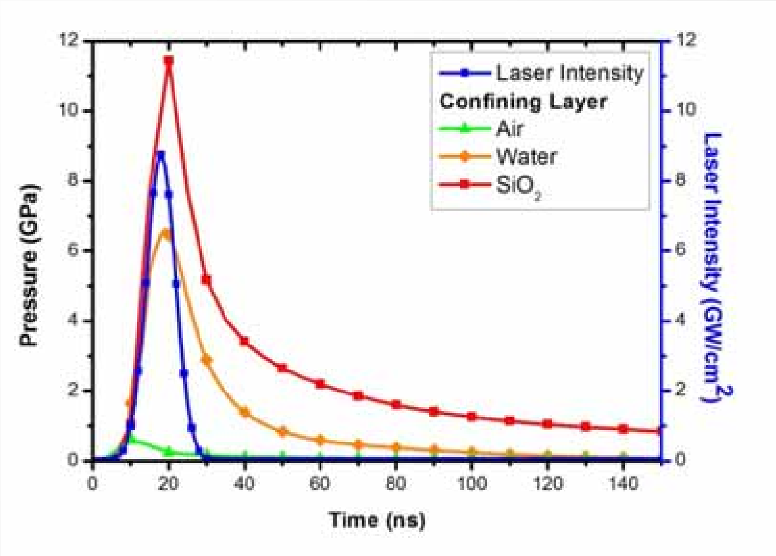


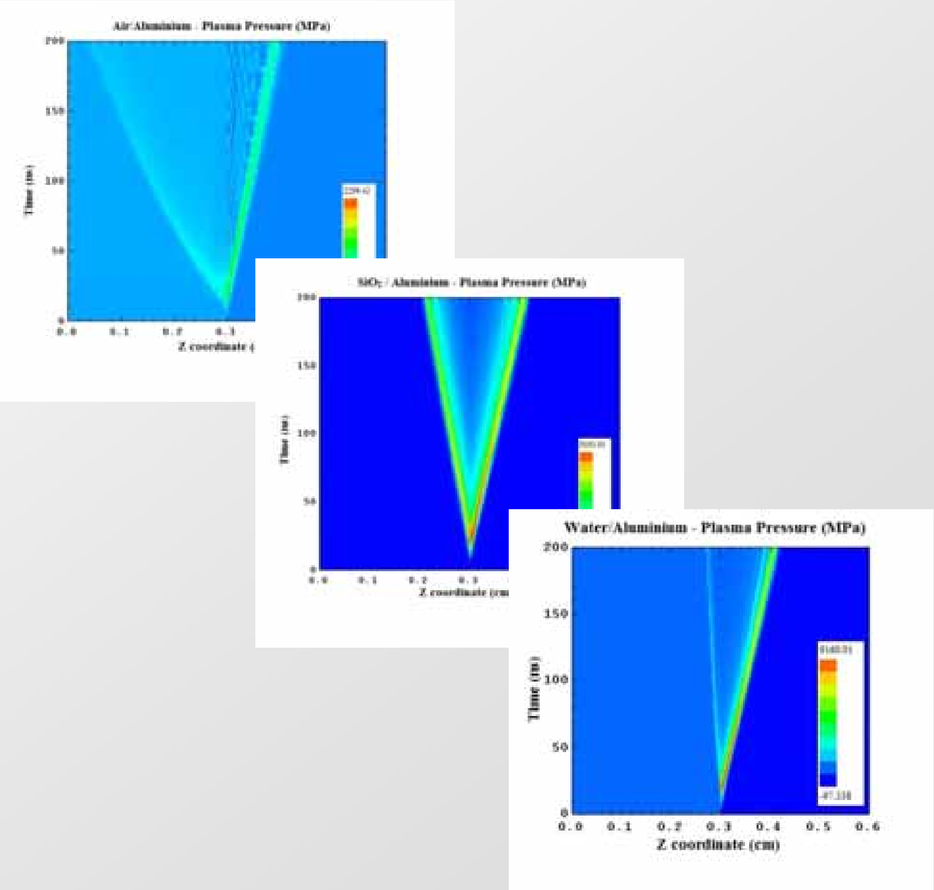


3. NUMERICAL SIMULATION RESULTS

HELIOS Analysis of relative influence of confining material



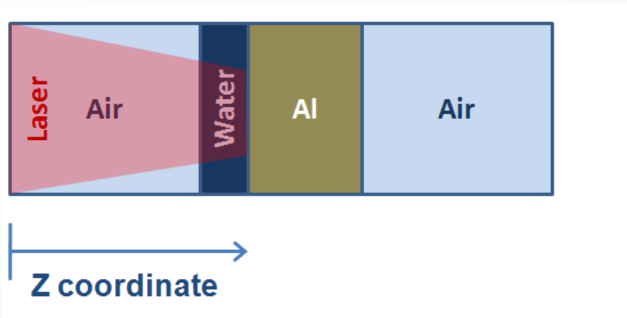


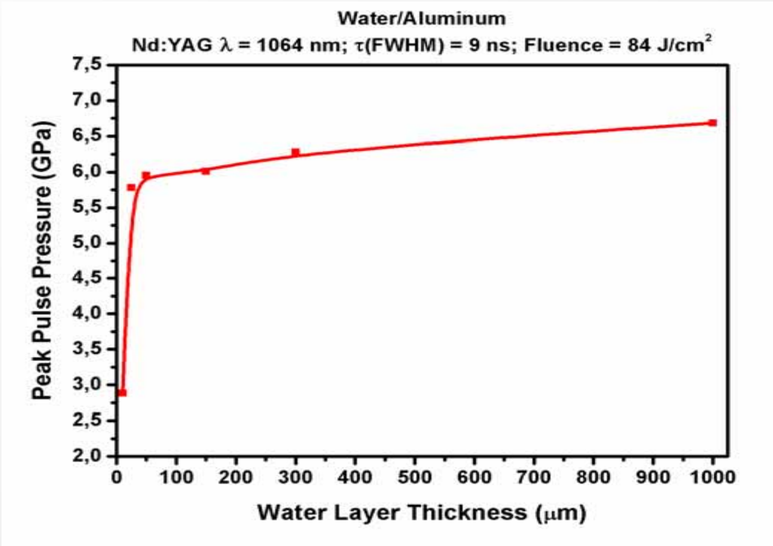


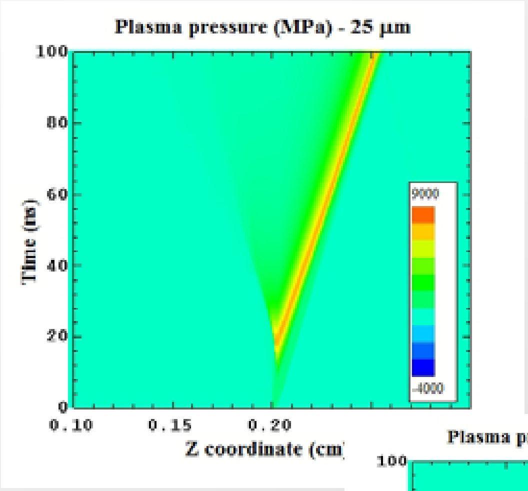
3. NUMERICAL SIMULATION RESULTS

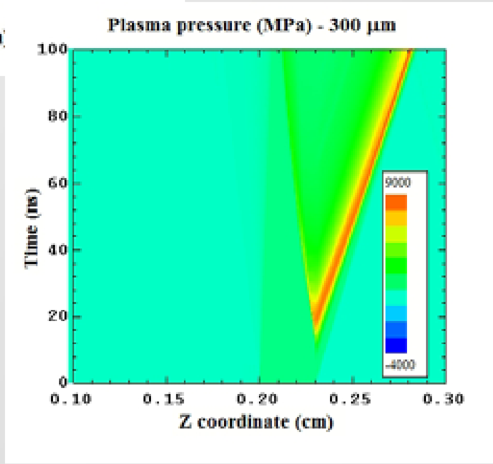
HELIOS

Analysis of influence of water layer thickness





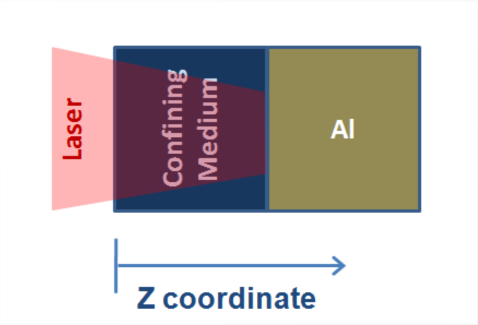


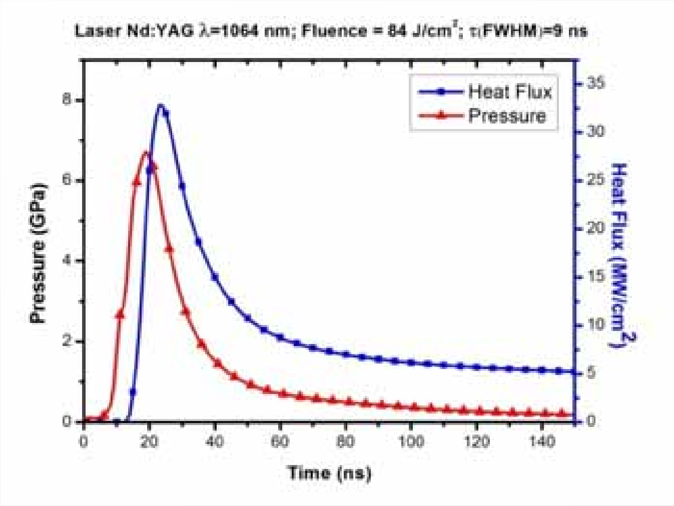


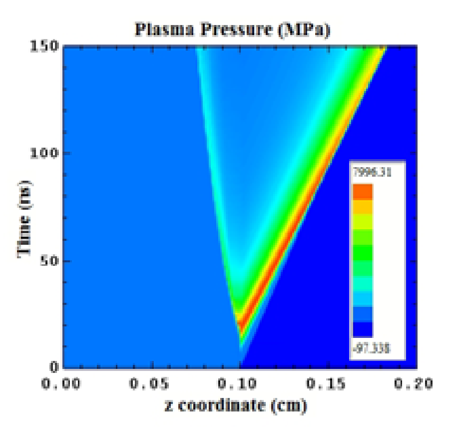
3. NUMERICAL SIMULATION RESULTS

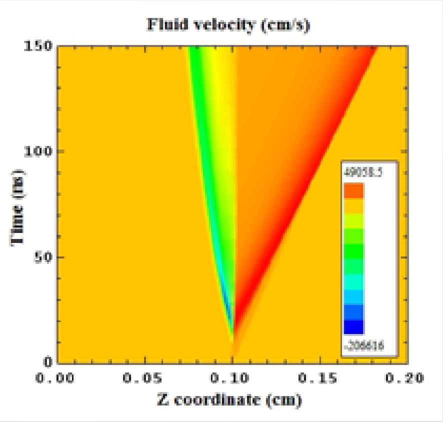
HELIOS

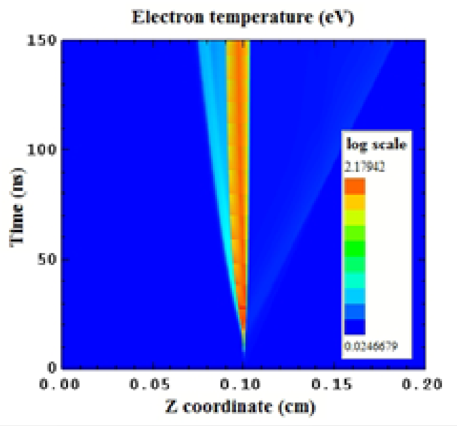
Analysis of plasma for LSP conditions

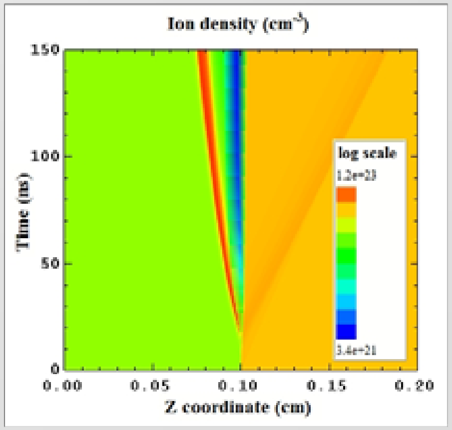




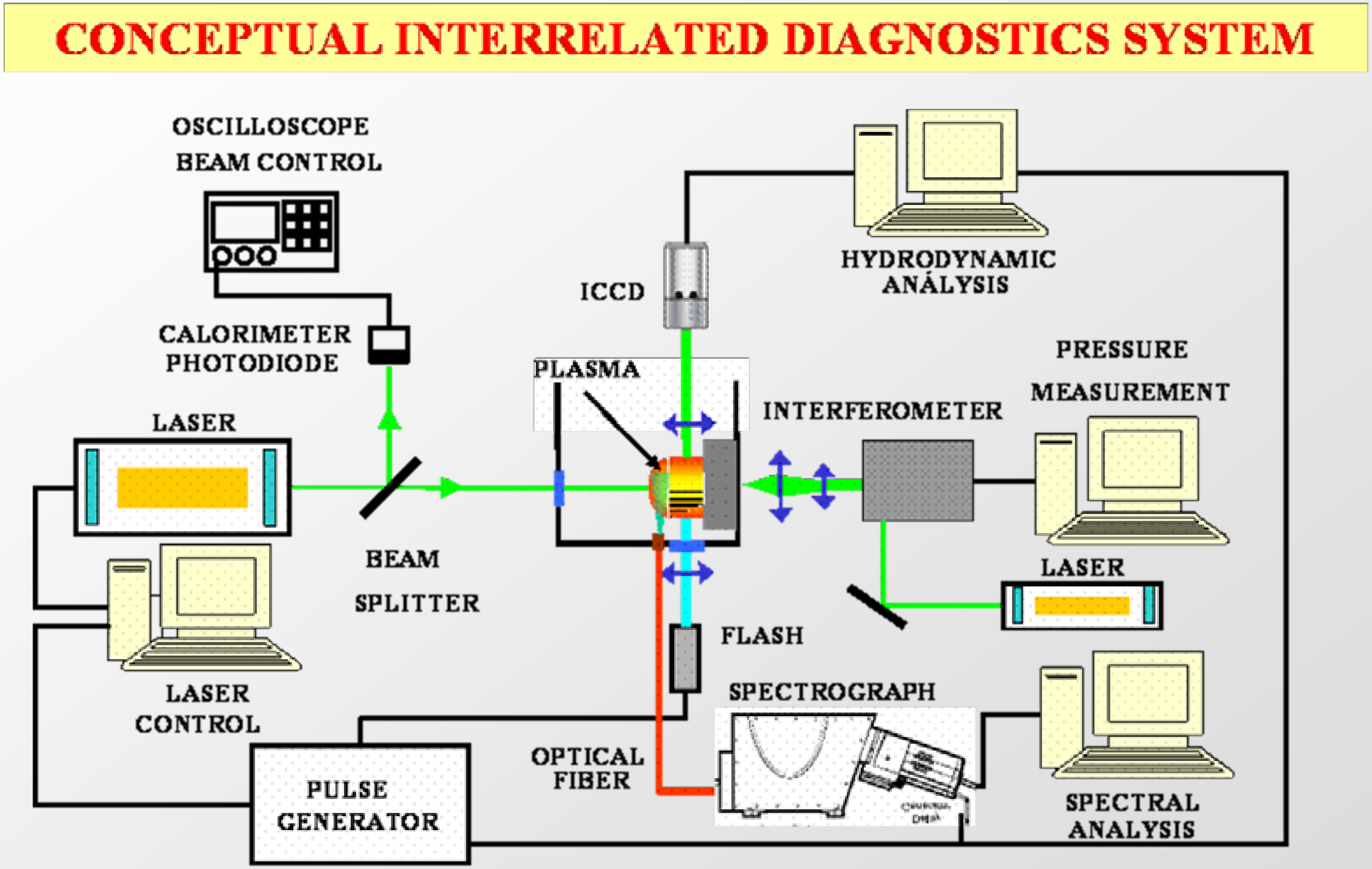






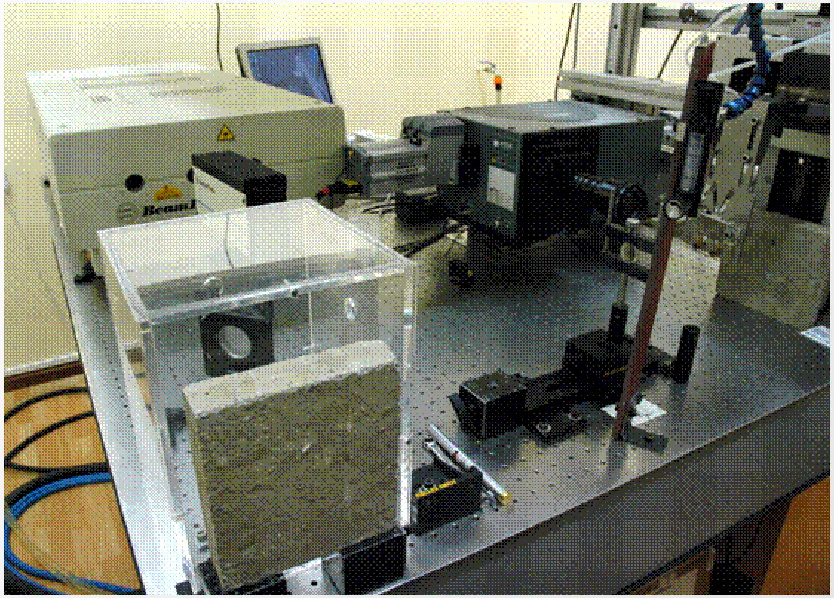


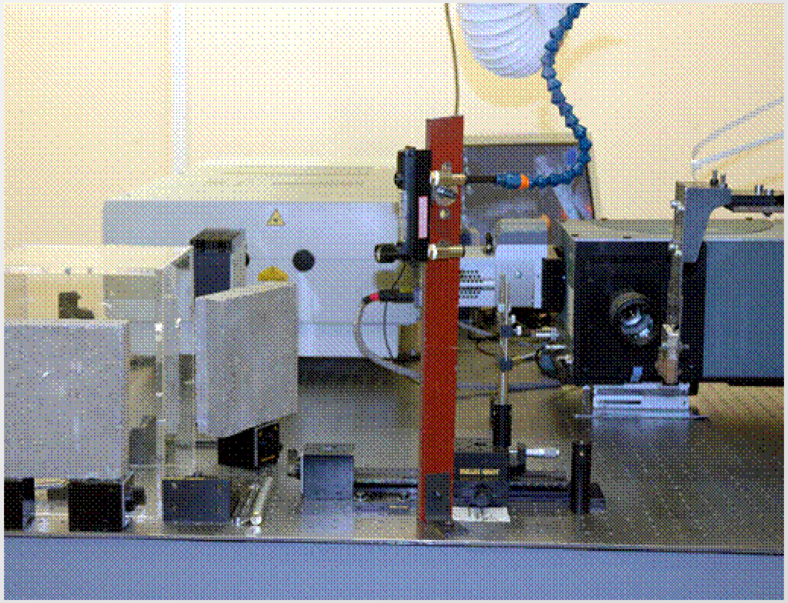
4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP



4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

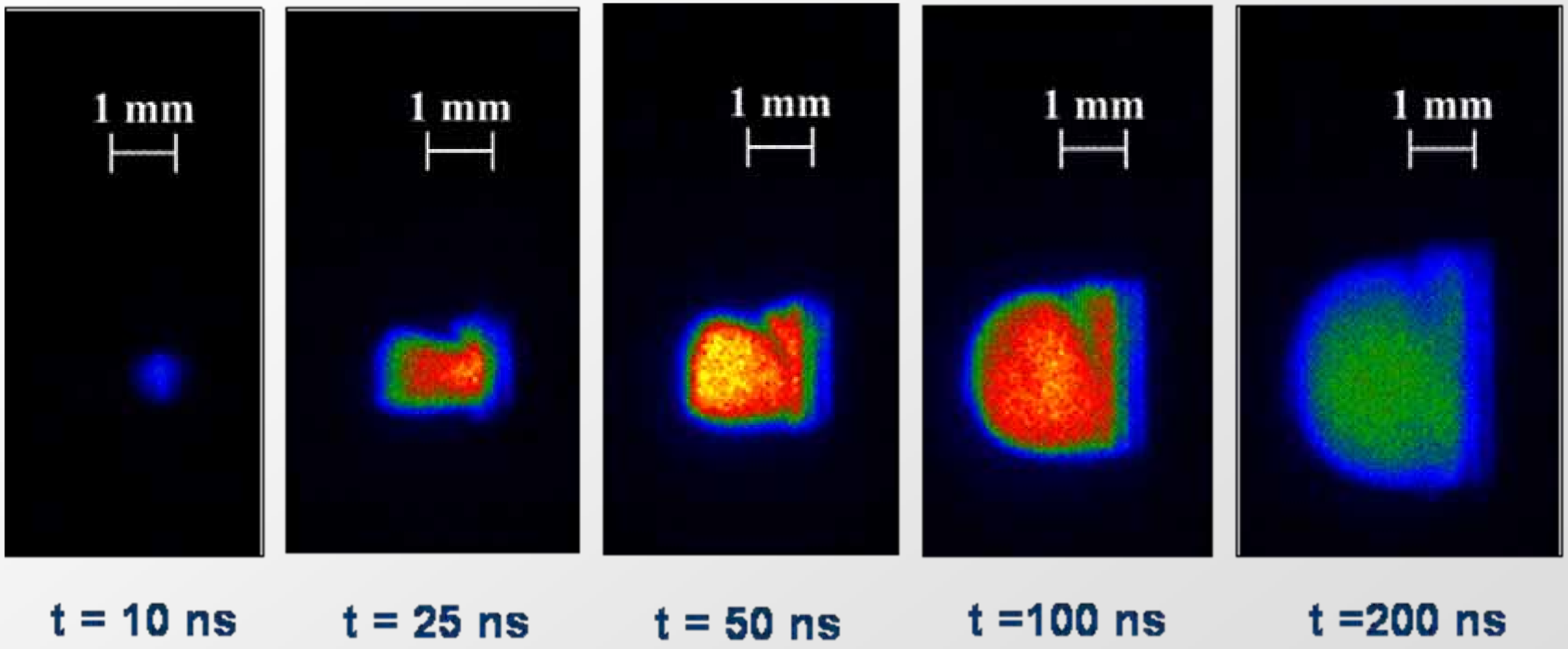
CONCEPTUAL INTERRELATED DIAGNOSTICS SYSTEM





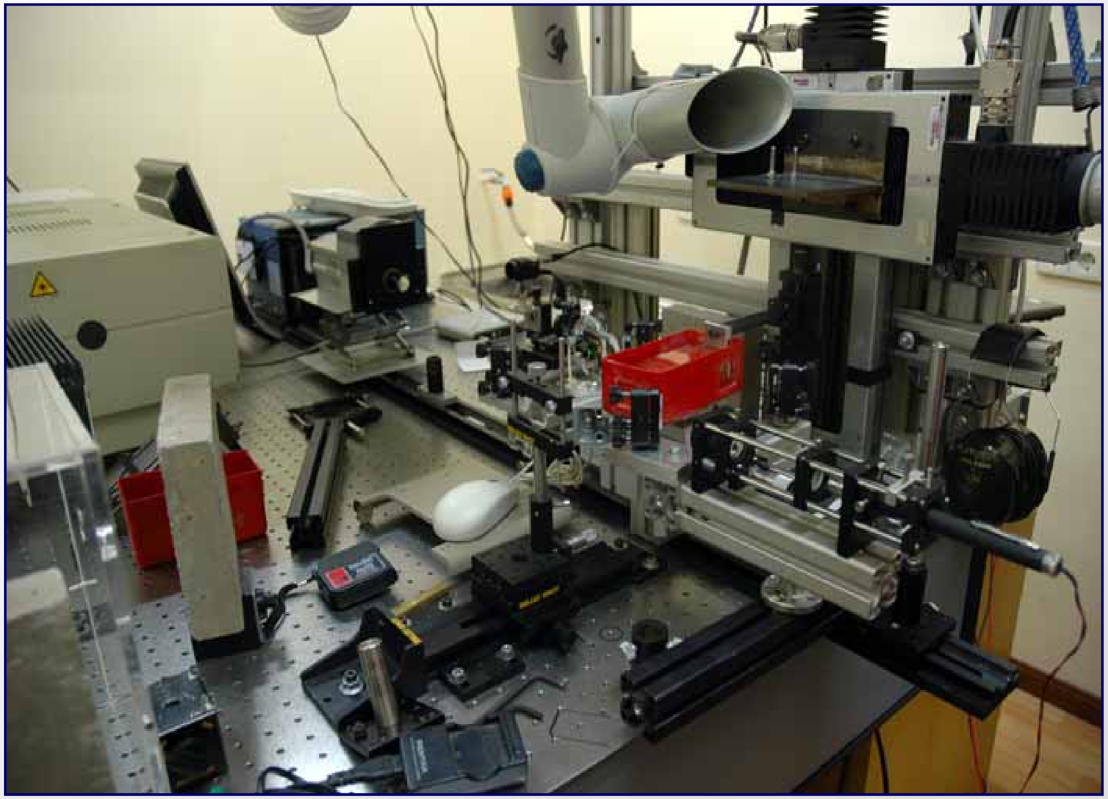
4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

DIRECT IMAGING - HYDRODYNAMIC ANALYSIS



4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

IMAGING TECHNIQUES – SCHLIEREN / INTERFEROMETRY



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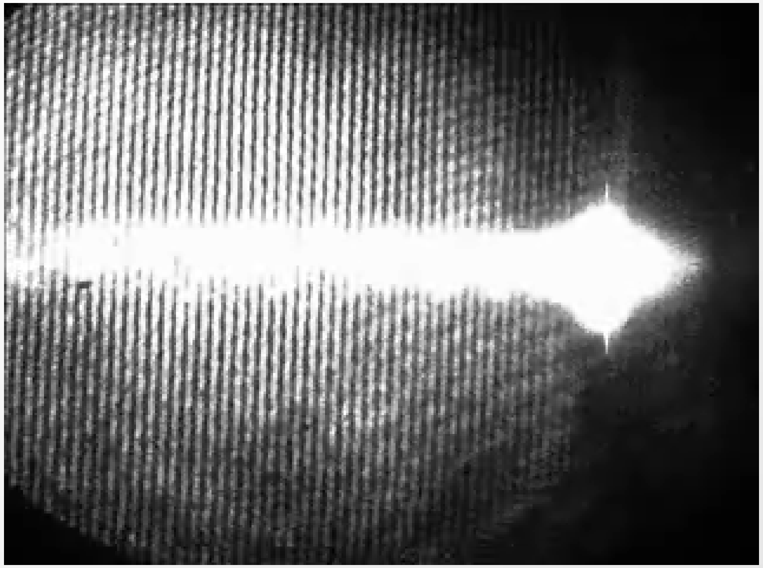

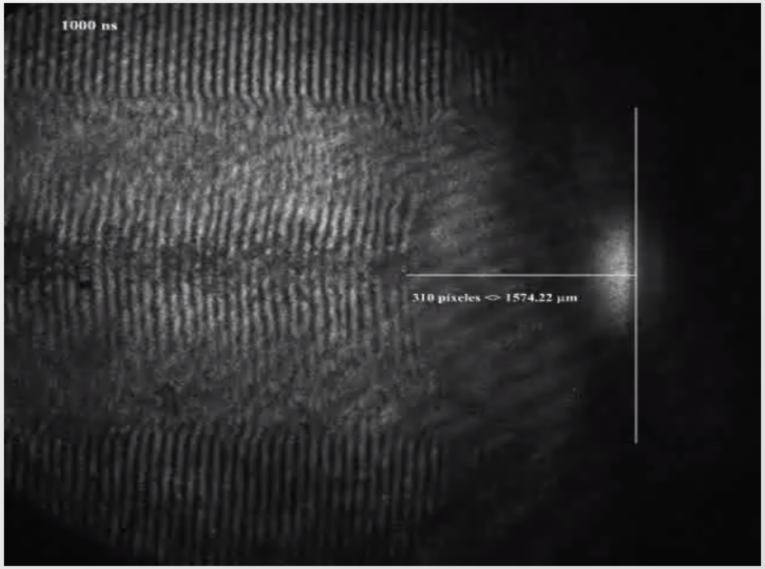

Martí-López, L. et al.: Appl. Optics, 48, 3671-3680 (2009)

4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

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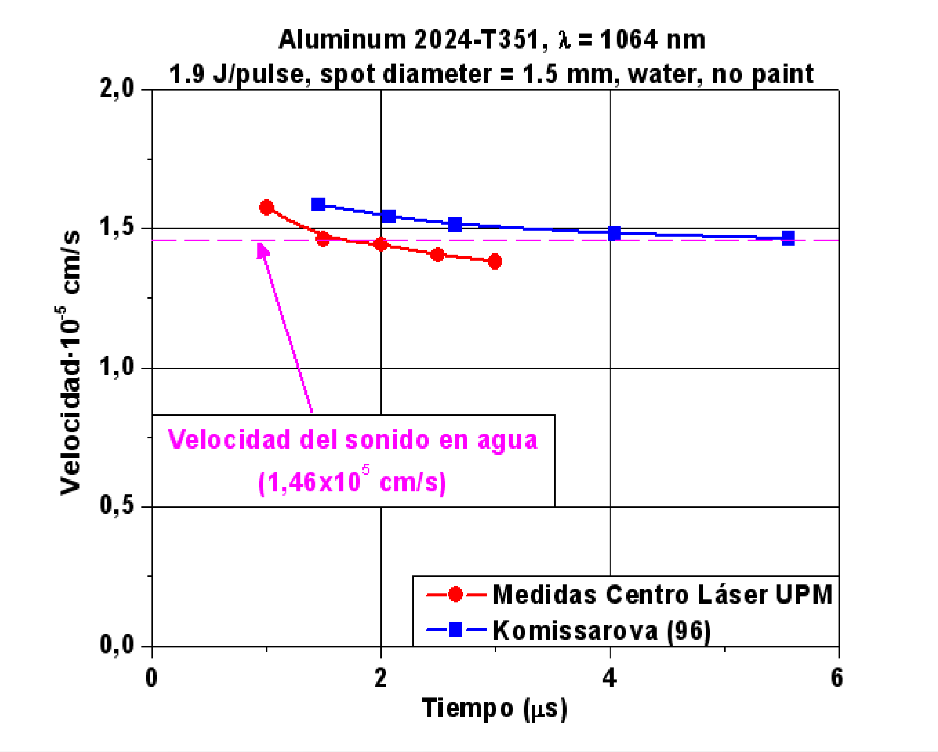

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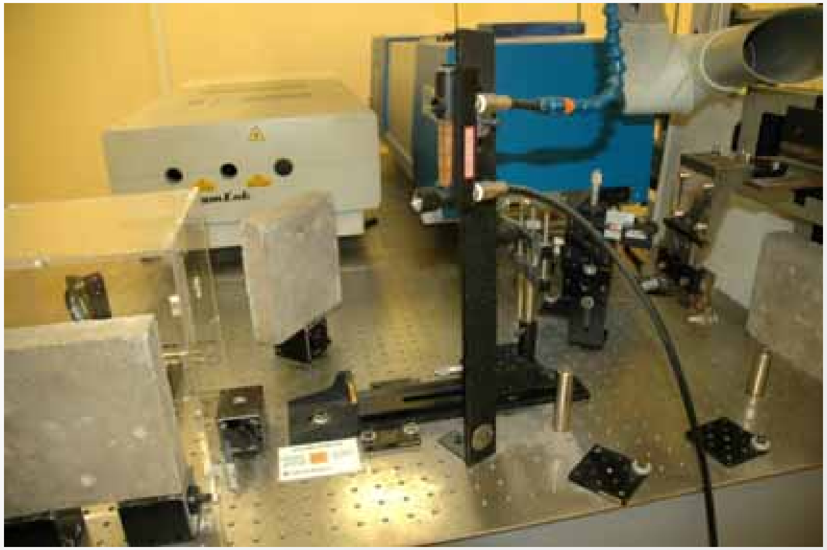
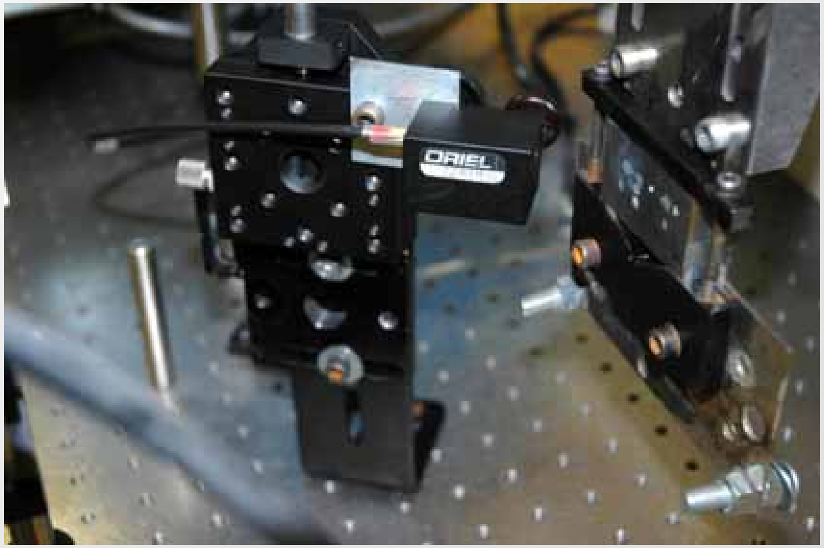
4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

EMISSION SPECTROSCOPY



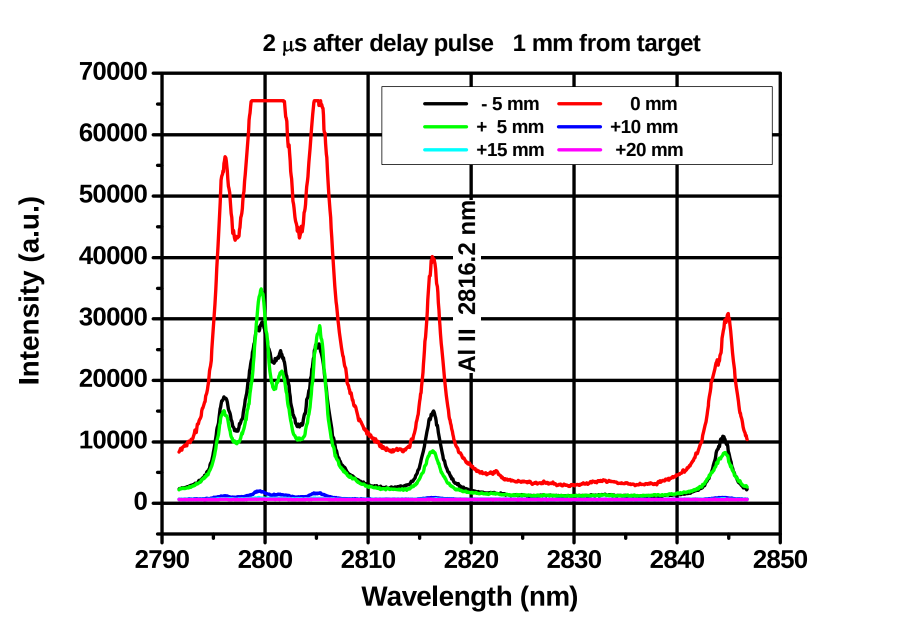


Spectroscopic system calibrated in wavelength with Hg lamp and in intensity with Deuterium lamp

4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

EMISSION SPECTROSCOPY

Electron density determination via Stark effect of Al II line at 2816,2 nm:

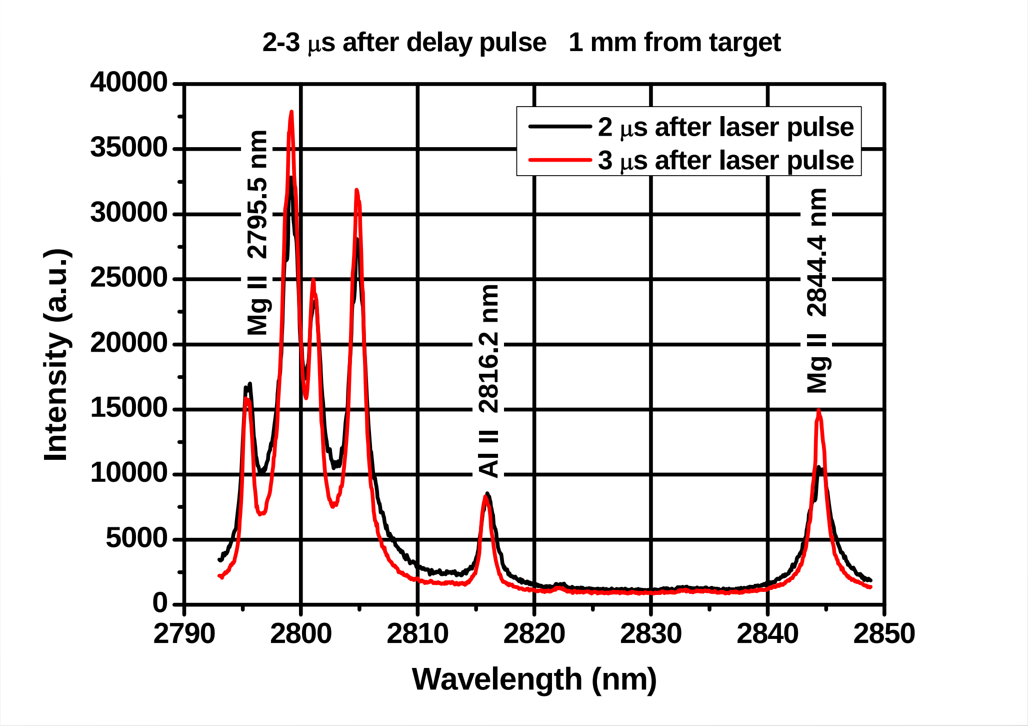


		Delay from laser pulse	
		2 μs	3 μs
Distance from target	1 mm	20.4 10^{16} cm^{-3}	2.4 10^{16} cm^{-3}
	6 mm	17.2 10^{16} cm^{-3}	2.0 10^{16} cm^{-3}

4. EXPERIMENTAL VALIDATION. DIAGNOSIS SETUP

EMISSION SPECTROSCOPY

Electron temperature determination through Boltzmann plot of relative intensities of Mg II lines at 279.5528 nm, 280.2704 nm, 292.8633 nm and 293.6509 nm:

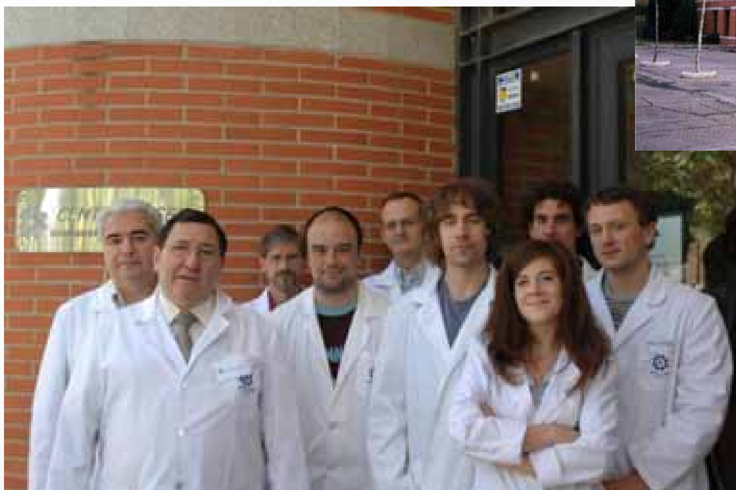


Preliminary electron temperature distributions in the range of 1.0-1.5 eV (i.e. ≅ 11 600 - 17 400 K) were found close to the target 2-3 μs after laser shut-down

5. DISCUSSION AND OUTLOOK

- The need for a practical capability of LSP process control in practical applications has led to the development of comprehensive theoretical/computational models for the predictive assessment of the complex phenomenology involved.
- High intensity laser-plasma interaction has revealed itself as a critical point for a proper process understanding and predictive assessment of LSP processes.
- The developed calculational model (SHOCKLAS) allows a systematic study of LSP processes starting from laser-plasma interaction. The integrated laser-plasma analysis routine, based in realistic material EOSs, provides a unique capability for process parametrization.
- Additionally, the development of the appropriate experimental diagnosis facilities and the connection of numerical simulation to experimental material characterization enable a fundamental and reliable process understanding capability in view of process industrial implementation.
- However, additional work is needed in order to connect experimental observations with theoretical code predictions for validation purposes.

The LSP Team at CLUPM



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